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A STUDY OF VARIATIONS OF MARQUIS WHEAT IN RELATION TO DIFFERENT SPACING OF PLANTS.

By George Earl DeLong.

University of Alberta,
(Department of Field Crops)

Edmonton, Alberta.
April, 1928.

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A THESIS

submitted to the University of Alberta

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INTRODUCTION.

Variation in variety type is causing considerable discussion among agriculturists who are interested in the production of registered seed grain. Variation in the type of Marquis has been the focus around which much of this discussion has centred. These discussions have given rise to numerous speculations concerning the amount of variation which is directly attributable to environment and maturity, and that which may be due to recombinations of parental characters resulting from natural crossing between the parent variety and other sorts which had their origin as mechanical mixtures or as sports of the parental variety. Agronomists agree that most populations of our cereal crops are each made up of several biotypes which fluctuate in varying degree from the accepted variety type; they do not agree, however, on the line of demarcation betweem fluctuation of variety type due to environment and aberrant biotypes which are the result of recombinations of parental characters.

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THE PROBLEM.

Saunders (12), Newman (9), and Clark, Martin and Ball (2) have described Marquis wheat. The descriptions given, however, apply to the average of the field crop but do not include the range of fluctuation within the type which may occur as a result of different environmental conditions and different degrees of maturity. Percival (10) states, "In no cultivated crop do we know how much of that which we see should be attributed to the response of the plant to the environment and how much to constitution". This difficulty stated by Percival is, in a word, the problem confronting the man interested in the production of Registered Seed of Marquis wheat.

In an endeavor to improve the seed stocks of Marquis wheat at the Dominion Experimental Station, Lacombe, Alberta, the practice has been to preserve the different selections as pure lines for at least two generations. The * L1 generation consists of a head row four feet long and the * L 2 generation consists of an increase plot of one row 66 feet long. These L 2 rows are always spaced one foot apart and are seeded on land which has been thoroughly summer-fallowed the previous season. It has been found that this method of increasing selections created a problem in that plants produced under such extreme environmental conditions differed morphologically from the originally selected parent plants which were grown under average field conditions.

* L 1 refers to the first generation of the progeny of an original head selection from an apparently pure stock; L 2, L 3, etc., refer respectively to subsequent generations.

The production of these morphological variations, which in this case are undoubtedly due to extreme environmental conditions, forces one to realize that environmental conditions may be responsible for wide deviations from the accepted Marquis type. This realization accentuated in general the difficulty of distinguishing between variations due to environment and those which may be due to differences in genetical constitution.

During the last few years field inspectors for the Canadian Seed Growers' Association have experienced difficulties of this sort. They have found numerous aberrant types in fields of Marquis, some plants with bearded heads, some similar to certain other known varieties as well as other plants unlike any recognized sorts. They have also found what is much more confusing, viz. plants diverging in varying degrees from the accepted Marquis type.

The object of this investigation has been to secure evidence that might assist in differentiating between maximum deviations from the standard variety type directly attributable to environmental influences and deviations arising from recombinations of genetical factors.

REVIEW OF PREVIOUS AND RELATED WORK

Percival (11) in discussing methods and value of selection states, "My conception of old established agricultural and horticultural varieties of our crop plants, is that apart from accidental mixture or outcrossing with different varieties, the several distinct lines usually discovered in them originate from mutation and subsequent crossing of the mutants with the parent type and with each other. True mutations, which I consider are in all cases responses of the plant to the environment, appear to be of great rarity, but only a few are needed to give rise to a large number of new forms by resorting and recombination of their factors and those of the parental form after crossing. The time taken for a recently isolated line to become an obviously mixed population of distinct lines will depend upon the frequency of mutation, and the facility for hybridization."

Percival appears to stress the importance of mutation and subsequent intercrossing as the source of aberrant forms. In the case of Marquis wheat, however, Newman (9) considers that most of the aberrant types found in Marquis consist very largely of mechanical mixtures. It would appear that, due to the prevalence of mechanical mixtures of other varieties, intercrossing is more probable between Marquis and these mechanical mixtures than between Marquis and mutant types.

Engledow and Wadham (6) in their yield studies found that, "In comparing pure lines on the single plant basis it is essential to confine observation to the "modal" tiller-number sub-population of each line. In no case can close comparison be of value if made in terms of general populations". This statement may apply

to yield comparisons but lacks significance in the identification of varieties as it is the plant falling between the "modal" form and either "extreme" which is most difficult to classify and which creates the problem.

They recognize fluctuation among cereal plants and the difficulty involved in their statement that, "Investigations upon metrical characters of cereal plants have always presented great difficulty on account of the range of fluctuation which is always encountered." They found that, "A field crop is a population of single plants enjoying different environments." They also found that, "Of the total sown, only a quarter to a seventh grow into mature plants. The losses are irregularly distributed so that many different spatial arrangements pertain in the field."

Later work by Engledow (3) revealed the fact that there was great irregularity in the rate of deposition of seeds by the seed drill. It was shown that, "The number of seeds deposited by the drill on any one-foot length of row is practically independent of the number on the preceding or next following foot", and "That "misses" and large "gaps" as well as the distribution of seeds by drills affects the development of the plants."

Engledow and Wadham (6) found a crop so variable that in an endeavor to lessen "fluctuation" in plants studied, suggested certain precautions of which the chief are:

> "Selection of seed, sowing on one day and by uniform dibbling, and the exclusion of plants which do not germinate in the "modal" period(of two days) for the whole population."

"A similar exclusion of the plants of end rows, of the end plants of all rows, and of plants one or both of whose neighbors in the row fail to survive till harvest."

"At later stages and for special purposes observation was limited to plants which "flowered on the "modal" day and which produced the "modal" number of ears."

They endeavored to eliminate "fluctuation" by using one tiller (the best developed) from each plant and suggest restricting experimental populations to plants all of which produce the same number of tillers.

Harrington (7) found considerable variation in type as among different strains of so-called Marquis wheat and also found considerable fluctuation as among individual plants within any strain of Marquis wheat. Of fifteen strains studied "Nine strains proved to be typical Marquis and six non-typical."

The variability of strains is shown by the following quotation from Harrington (7); "In taking data on the progeny plants the spikes that were most like the parental spike in size were chosen for measurement. This was done because it was observed that relatively large difference in spike density and in glume characters existed among the fully mature spikes of a single plant. The largest spike of each plant proved less accurate for use in comparing one plant with another than a well developed spike of approximately the average size for the strain. To insure accuracy in the comparisons progeny spikes differing from the parent spike by more than 10 percent in length were not used excepting in a few cases where spikes of the average size were not available."

Kiesselback and Sprague (8) in studying the relation of the development of the wheat spike to environmental factors found that

"the number of plants per unit area averaged 92% as great on poor locations as on good ones, and since the difference favored the individual plant development on the poor locations, it would tend to make them more nearly alike rather than to accentuate the plant differences. Tillering was reduced from 3.3 to 2.0 spikes per plant by poor locations and the total number of spikes per unit area was reduced 45%. The number of grains per spike was 24% less on poor locations and since average kernel weight was practically the same (4% higher on the poor soil), the reduction in yield from 32.2 bushels to 14.4 bushels was due primarily to fewer spikes with fewer grains. The loss in number of grains per spike is due to the 12% reduction in number of fertile spikelets and the 14% decrease in grains per fertile spikelet. Spike length reduced from 2.4 inches on good locations to 2.1 inches on poor locations. With reduced spike length there was a corresponding reduction of 12% in number of spikelets per spike." They found that "Environmental conditions which reduce vegetative growth generally cause a reduction in tillering, culm length, spike length, number of fertile and total spikelets per spike, grains per spike, grain and straw yields, average kernel and culm weights, grains per fertile spikelet, and percentage of fertile spikelets."

The foregoing review indicates the great variability which different investigators have observed in cereal plants. Had these investigators been endeavoring to study variability instead of trying to eliminate it from their studies, in all probability a greater bulk of information concerning variability would now be available.

METHODS OF CONDUCTING RESEARCH

The Dominion Experimental Station, at Lacombe, Alberta, was asked by Mr. G. M. Stewart, District Inspector, Dominion Seed Branch, Calgary, Alberta, to co-operate in a study of variations in Marquis wheat which might result from planting under different spacing conditions. Mr. Stewart suggested a seeding plan and offered to supply the purest strain of Marquis 10 B available -- Marquis 10 B was found to be one of the purest strains by Harrington (7) ahd Newman (9). The conduct and completion of the study came under the writer's immediate supervision. The data collected in this study appeared so interesting that, in view of the absence of similar data, it seemed wise to put it on permanent record.

Original stock seed of Marquis 10 B wheat was sown in the normal seeding season on a dark loam soil which had been thoroughly summer-fallowed the previous year. In Lot 1 plants were grown in drills seven inches apart at the rate of six pecks per acre. In Lot 2 the plants were grown in drills spaced eighteen inches apart with the plant distribution in the drill similar to Lot 1, and in Lot 3 the plants were spaced eighteen inches apart each way. It will be noted that these lots were again divided into (a) and (b); (a) refers to fully matured portions and (b) to immature portions of plants. Thus (2a) refers to mature portions of plants from drills spaced eighteen inches apart and (2b) to immature portions of plants from drills spaced eighteen inches apart. There was an abundance of moisture available to the crop which made a strong, vigorous growth. Lot 1 was the only plot which appeared mat-

ure when the crop was harvested. The plants of all lots were pulled with roots intact on September 14.

One hundred counts or measurements for each character studied were made when collecting the raw data. While a larger number would have made the work more accurate, it was felt that the number used would indicate the possible trend of the variations. The use of one hundred counts or variates simplified the mathematical calculations. That they were sufficient in number to give fairly accurate results is indicated by the relatively low probable errors obtained.

In presenting this paper the writer has endeavored to draw a statistical *picture of the deviation from the mean variety type and thus to provide some information as to what variation one might attribute to environment. The graphic representations are given to assist the reader to understand and visualize the variation in the different characters studied. In these graphs the length of the cross-lined portion from the origin toward the right indicates the value of the minimum for the character in question; the length of the cross-lined section plus the heavy horizontally lined represents the mean value, while the total length represents the maximum value of the character.

* "Principles and Methods of Statistics" by Chaddock (1) was used as a guide for the mathematical calculations.

FINDINGS

Number of Tillers Per Plant

Engledow and Wadham (6) state that "a direct study of the nature and amount of "plant to plant fluctuation" with graminaceous plants indicates that the most obvious and potent factor in this fluctuation is likely to be the phenomenon of tillering." They also state, "There is a seminal root system whose precise share in the activities of the whole plant has never been determined, and in addition, every tiller develops an adventitious root system of its own. Whether among the tillers there can occur a translocation and interchange of the products of root absorption and photosynthesis, it is impossible to say. Possibly a graminaceous plant should be regarded as a unit--not in the same sense that a plant of e.g. Helianthus annuus is so regarded--but as a colony of individuals the younger at first dependent on the others but later, self established and competing with them." They conclude that "tillers are of different ages, physiologically as well as chronologically."

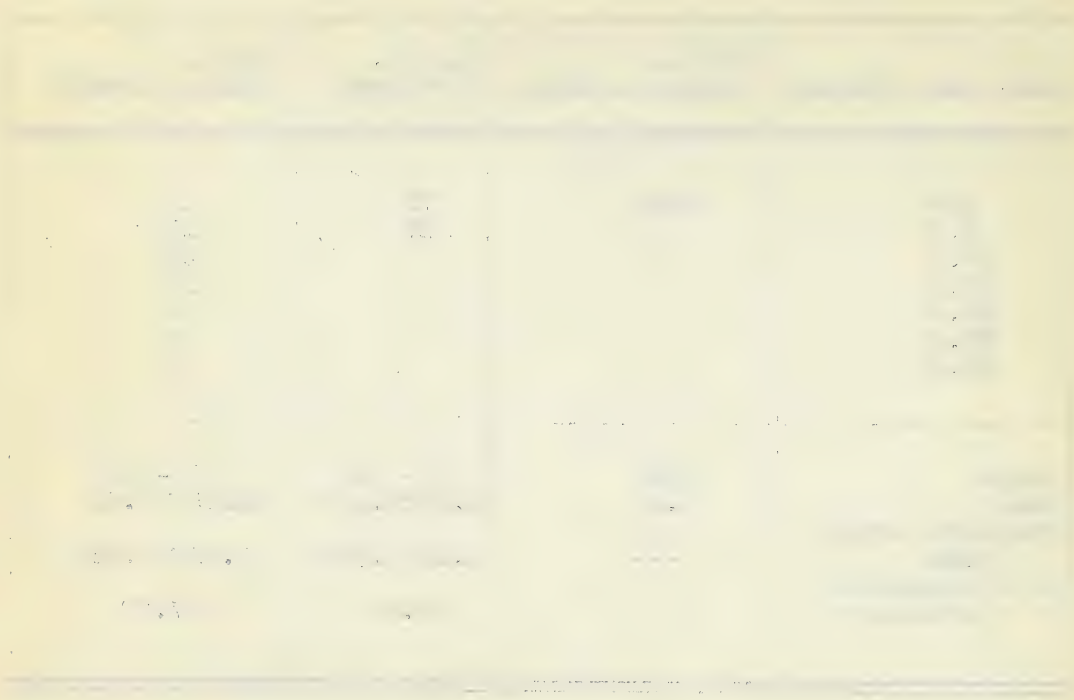
Percival (10) considers the cereal plant as a colony of individuals (tillers) rather than a unit. The main axis of the plant is supported by the seminal root while the tillers or laterals are largely supported by adventitious roots which develop during the formation of the tillers. The number of tillers per plant has but little significance in the differentiation of Marquis strains. On the other hand, this character responds quickly to environment and thus is of value in that it indicates

to some extent the possible variation in plants due to environmental conditions. Although of little significance in itself, if linked up with other variable characters, it may help form a chain of evidence that will throw new light on the subject in question. In any case, it is a variable character and since we are studying variability it would be unwise to omit a study of what is possibly the most variable of plant characters.

TABLE I

Number of Tillers per Plant.

Mid-class Values	Lot 1. Normal seeding	Lot 2. 18" Rows	Lot 3. Plants 18"x18"
2.5	100	73	3
7.5		27	25
12.5			43
17.5			15
22.5			6
27.5			2
32.5			5
Range	1-5	2 - 12	3 - 33
Mean	2.53	3.83±0.158	13.65 ± 0.43
Standard Deviation	-----	2.23±1.048	6.52 ± 3.064
Co-efficient of Variation	-----	57.90	47.70



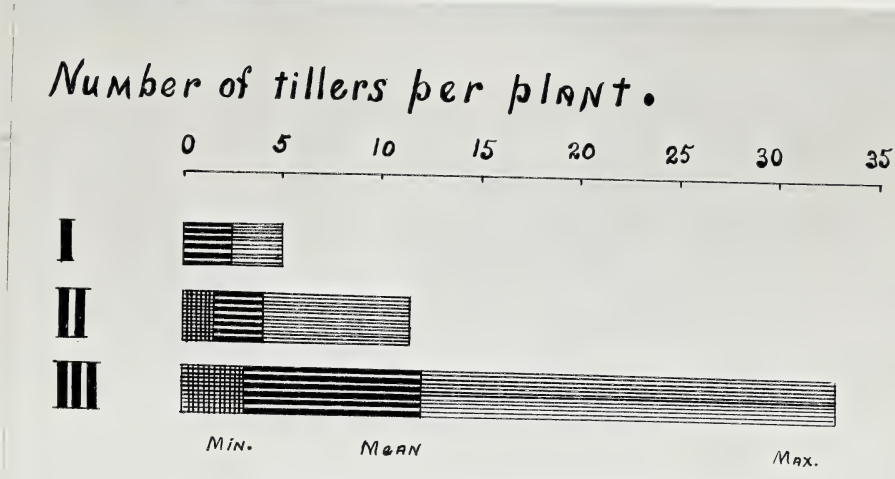


Fig. 1. Number of tillers per plant. The wide range of variation, the minimum, mean and maximum number of tillers per plant are represented.

It will be seen in Table I and Fig. 1 that the number of tillers per plant showed a wide range of variation. Table I illustrates the distribution frequencies for the number of tillers in the different lots. It will be seen that the mean number of tillers per plant increases as the plants are allowed more room to develop. This is in agreement with the findings of Engledow and Skelton (5) who found that "within limits, the more vigorous the plant the more tillers it produces; and the facts displayed make it appear that greater vigor is evinced in "all-round" form--not only more tillers but bigger ones (larger glumes and rachis)"

It is interesting to note in Table I and Fig. 1 that while the mean number of tillers of Lot 3 is approximately four times that of Lot 2, the Standard Deviation of Lot 3 is only three times that of Lot 2 and the co-efficient of variation of Lot 3 is actually less than Lot 2.

The great variation in the number of tillers per plant indicates the response of this character to spacing. The study of this character has not revealed any point of particular significance except, that, since the plant shows such wide variations in number of tillers per plant when grown under different spacing conditions, it would appear possible for it to vary in other characters as well.

Length of Tillers

The length of tiller at first thought might appear to have no particular significance in a study of wheat variation. It is true that the normal fluctuation in the length of the tiller has little value in differantiating between Marquis and aberrant

types; on the other hand, very tall tillers growing in fields of Marquis have always raised a question concerning their probable origin. The study of the length of tiller was made in an endeavor to obtain information on this problem.

Engledow and Wadham (6) state, "the main axis is usually bigger in all respects than the first side tiller which, in turn, is bigger than the second, et seq." This observation holds true in most cases but exceptions are not infrequent in Alberta. An outstanding exception is the crop of 1924 wheat. A large proportion of this crop was seeded on a soil which contained practically"no moisture carry over" from the previous season. There was a subnormal amount of precipitation during April, May and June with the result that the wheat made a subnormal growth, developing but few tillers per plant, and these below normal in length. Heavy rains occurred during July. These rains falling on the warm fertile soils stimulated the wheat plants into a second tiller developing stage. These late tillers continued to develop and were in the bloom stage when the first tillers formed were fully mature. These late tillers were approximately one foot taller than the mature tillers on the plants from whence they sprang. They constituted fully 50 percent of the crop as harvested and did not attain a greater maturity than the milk stage before fall frosts occurred. They proved a serious detriment to this crop as the threshed grain, because of the large percentage of immature kernels, graded "feed".

A further exception to the rule that each succeeding tiller is shorter than the one from whence it sprang has been observed when frosted seed is planted under conditions not ideal with

respect to growth. As a rule a rather weak plant is developed, which produced a relatively small number of rather short tillers. If growth conditions improve during the growing season, a relatively large number of late maturing tillers may develop, a few of which are usually taller than the earliest maturing tillers of the same plant.

TABLE II.

Length of Tillers in Inches

Mid Class Values	Lot 1. Normal Seeding		Lot 2. 18" Rows		Lot 3. Plants 18" x 18"	
	(a) Mature	(b) Immature	(a) Mature	(b) Immature	(a) Mature	(b) Immature
22.5				1		13
27.5				2	7	18
32.5		6		4	45	34
37.5	1	22		21	44	20
42.5	33	65	21	37	4	8
47.5	65	7	54	29		7
52.5	1		25	5		
Range	39.5 - 50.0	31.5 - 46.0	41.0 - 54.5	24.0 - 52.0	25.5 - 40.5	14.5 - 46.0
Mean	45.8 ± 0.172	41.15±0.228	47.7 ± 0.229	42.45±0.231	34.35±0.231	32.65±0.459
Standard Deviation	2.55±0.120	3.88±0.169	3.39± 0.169	5.5 ± 0.258	3.43 ± 0.16	6.80 ± 0.32
Co-efficient of Variation	5.60	8.20	7.10	12.90	9.90	20.80

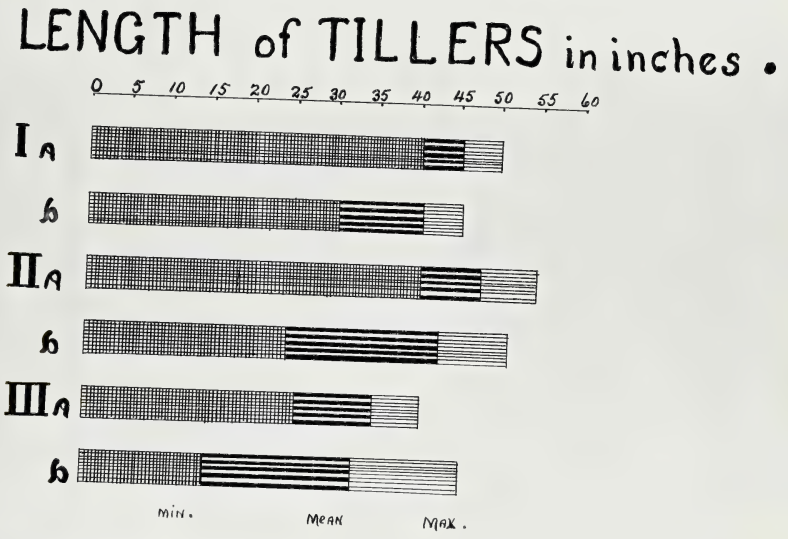


Fig. 2 Length of tillers in inches. The range, minimum, mean and maximum length of tillers is represented.

The length-of-tiller data given in Table II and illustrated in Fig. 2 reveals some interesting findings. The standard deviation indicates that the variation in the length of tiller increases as the plant was allowed more room to develop. It will also be seen that there is a much greater variation in the length of the immature tillers than there was in the fully mature tillers of the same group.

The range of the variation in the length of tiller is of particular interest in that the upper extremes of the range frequently create a problem. These tillers which diverge so far from the mean create a problem in that they may be mistaken for a longer strand variety when in reality they might be the result of a condition described by Engledow et. al (6) as "the chance synchronization of a weather-change and a sensitive development phase."

A further study of these data show that the mean height of Lot 2 is greater than Lot 1 but that the mean height of Lot 3 is less than that of Lot 1 or 2. This leads one to infer that the development of an excessive number of tillers may retard the development of length in the primary tillers. In other words the development of a greater number of tillers than the optimum represented in this case by Lot 2 results in a sacrifice in the length of the first tillers formed.

It will be observed that an increase in the number of tillers, Table I Lot 3, is associated with greater variation in length and a greater range between the minimum and maximum ex-

tremes. It seems quite possible for the tallest tillers to deviate so far from the mean that they are apt to raise a doubt in the mind of the observer as to their parentage when observed under field conditions.

Number of Heads Per Plant

The number of heads per plant is of no particular significance except that it is an indication of the response of the variety to spacing. The groups were divided into two classes, mature and immature (designated "a" and "b" respectively in the tables) when the counts were made. Heads which were considered mature had fully developed grain and glumes turning yellow. Heads which had not progressed past the medium dough stage were considered as immature.

TABLE III.

Number of Heads per Plant.

Mid Class Values	Lot 1. Normal Seeding		Lot 2. 18" Rows		Lot 3 Plants 18" x 18"	
	(a) Mature	(b) Immature	(a) Mature	(b) Immature	(a) Mature	(b) Immature
0	5	20	38	1		
1	36	54	27	8	10	1
2	42	18	26	32	29	3
3	14	7	8	28	21	4
4	3			21	12	9
5			1	4	14	7
6		1		1	7	10
7				3	2	7
8				1	2	14
9					1	12
10				1	2	10
11 & over						18
Range	0 - 4	0 - 6	0 - 5	0 - 10	1 - 10	1 - 21
Mean	1.74±0.058	1.17±0.063	1.08±0.071	3.05±0.134	3.5±0.134	7.39±0.177
Standard Deviation	0;87±0.041	0.94±0.053	1.05±0.049	1.55±0.073	1.98±0.093	2.62±0.123
Co-efficient of Variation	50.0	80.40	97.20	50.10	56.60	35.40

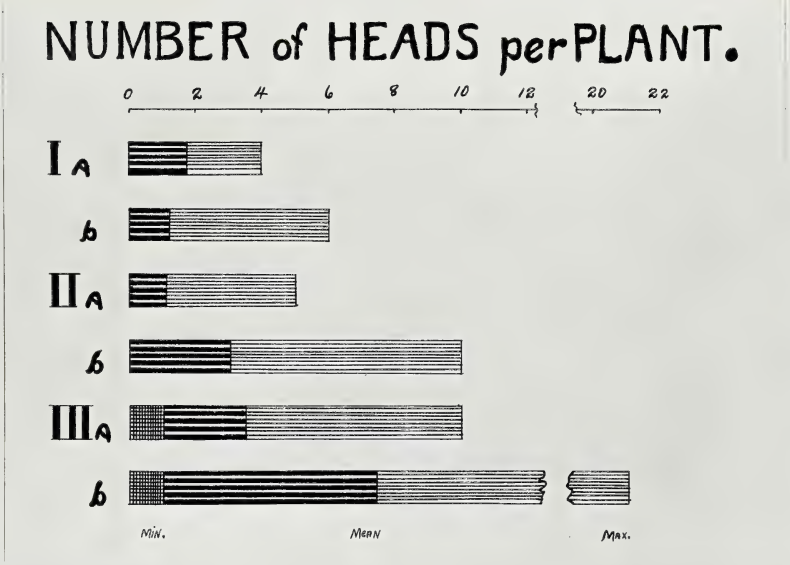


Fig. 3. Number of heads per plant. The range, minimum, mean and maximum number of heads per plant are represented.

The data relating to the number of heads per plant is given in Table III. A study of this data reveals the fact that there were plants in Lots 1 and 2 which did not have fully mature heads as well as plants which did not have any immature heads. It will also be seen that the number of mature heads per plant was almost equal in these two groups; hence the principal difference in the number of heads per plant in these two groups consisted largely of immature heads. The heads carried on the main axes of the plants in these groups matured at approximately the same time. The apparent difference in maturity of these groups no doubt is due to the greater number of late maturing tillers in Lot 2. Had spacing influenced the maturity of the head borne on the main axis there would in all probability have been no mature heads produced in Lot 3. The fact that the heads borne on the primary tillers appeared to be of similar maturity and that there were more mature heads per plant produced in Lot 3 than in the other Lots is a further indication of late maturing tillers being responsible for the late and uneven maturity in wheat crops that have a thin stand.

The range and standard deviation as shown in Table III and Fig. 3 indicate that the variation in the number of heads per plant is more extreme as the plant is allowed more room to grow. It is rather surprising to find that the co-efficient of variation tends to become less in immature plants and as the plants are allowed more room. This is to be accounted for by the great increase in the mean in Lot 3 over the other lots and

relatively much less increase in Standard Deviation.

The relative maturity of the heads of the three Lots was not studied in a statistical way. Observations made indicated that the relative maturity of the primary tillers showed but little variation, but had the immature tillers been included and means and ranges established there would have been considerable variation in the three Lots as the maturity of the tillers in Lot 3 varied all the way from fully mature to the flowering stage. It would appear as though a wheat plant, providing environmental conditions were favorable, would continue to send out tillers indefinitely, each successive tiller being a little later "physiologically as well as chronologically." It therefore seems reasonable to assume that one should allow considerable latitude in maturity and related factors when considering fields growing under conditions which favor the development of late maturing heads.

Length of Heads

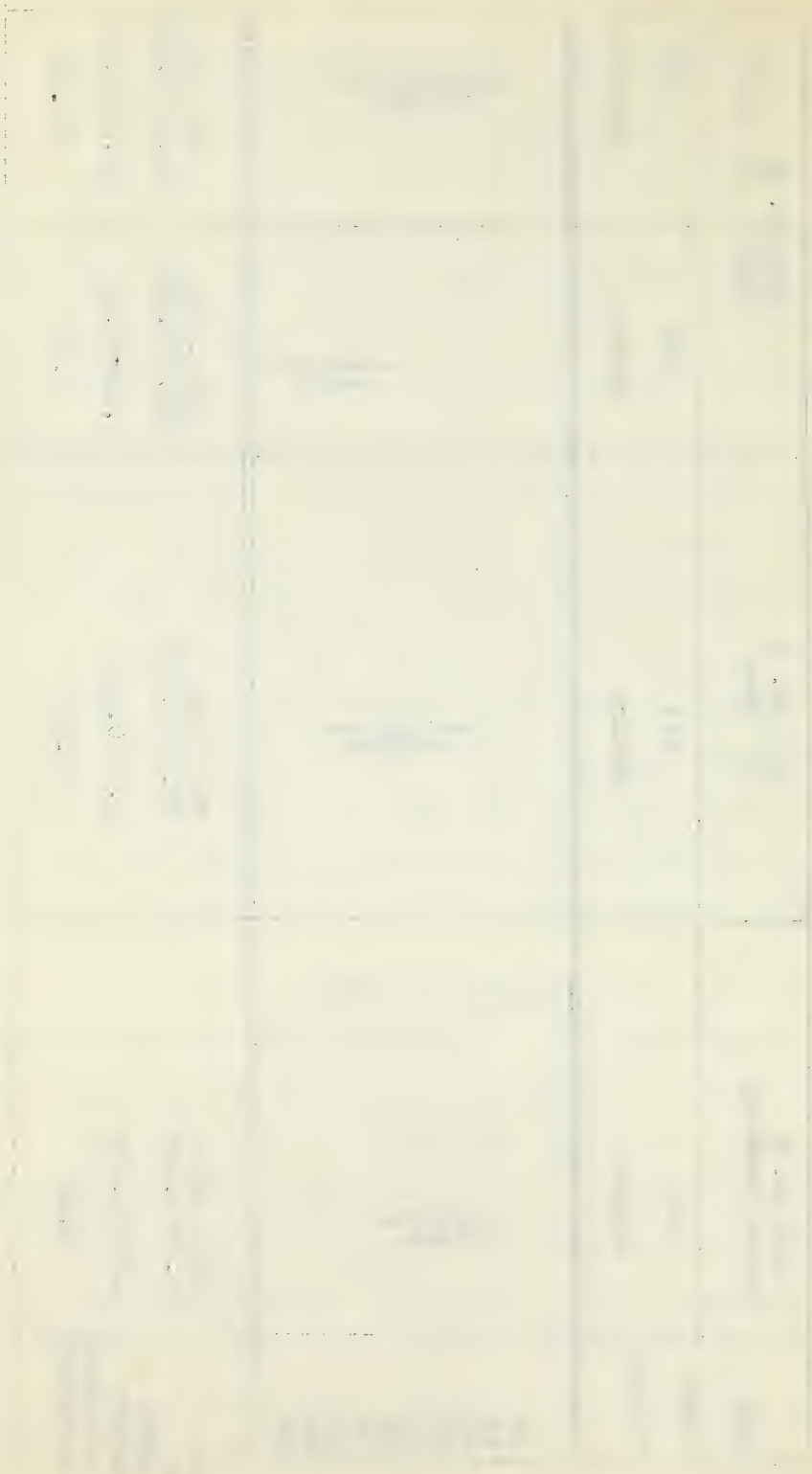
The measurement for length of head was made from the base of lowest spikelet to the tip of the uppermost spikelet. The apical awns were not included in the measurement.

The variation in length of head itself is of no particular significance. It might naturally be expected that an increase in the length of head would be associated with an increase in the length and number of tillers per plant. Length of head when associated with density of head, however, is one of the most important characters used in differentiating wheat varieties.

TABLE IV.

Length of head in m.m.

Mid Class Values	Lot No. 1 Normal Seeding (a) Mature	Lot No. 2 18" Rows (a) Mature	Lot No. 3 Plants 18" x 18" (a) Mature	Lot No. 3 Plants 18" x 18" (b) Immature
55				1
65	1			4
75	21	9		11
85	39	19		25
95	34	29		38
105	5	30	1	11
115		11	11	7
125		2	52	3
135			32	
145			4	
Range	65 - 105	75 - 125	105 - 145	55 - 125
Mean	87.1 ± 0.184	97.1 ± 0.705	127.7±0.503	92.1 ± 0.899
Standard Deviation	2.73 ± 0.128	11.94±0.561	7.43 ± 0.35	13.34±0.667
Co-efficient of Variation	3.10	12.30	5.80	14.50



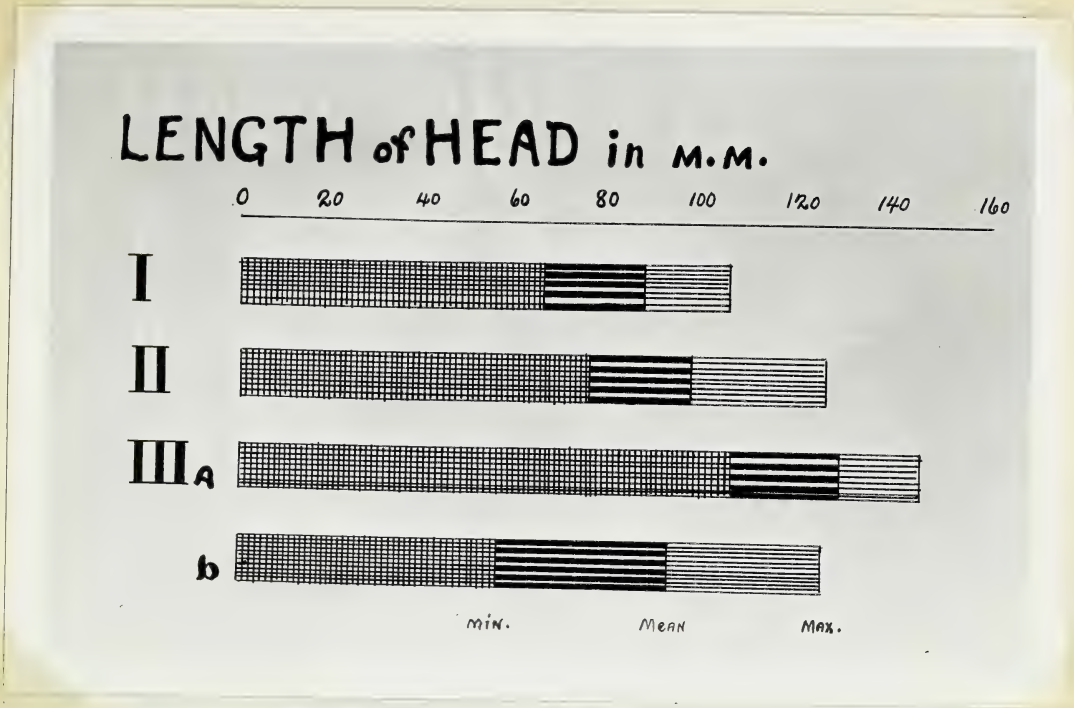


Fig. 4. The length of head. The range, minimum, mean and maximum length of head is represented.

The data relating to length of head given in Table IV and illustrated in Fig. 4 shows that there is great variation in this character. Not only is there great variation between groups but there is an even greater range of variation within a group. The great range of variation in length of head in the variety as a whole is indicated by the minimum of 55 m.m. and the maximum of 145 m.m. It is rather interesting to find that although the immature heads of Lot 3 are by far the most variable in length, the mature heads of the same Lot are less variable than the mature heads of Lot 2. The mean length of head data shows that the length of the head increases as the distance between plants becomes greater.

Number of Spikelets Per Head

No separation of fertile and infertile spikelets was made in this study. It was observed that infertile spikelets were practically absent in Lot 3, that they would average approximately one per head in Lot 2, and approximately three per head in Lot 1. The total number of spikelets per head less the number of infertile spikelets would have shown greater differences among the different groups.

TABLE V.

Number of Spikelets per Head.

Mid Class Values	Lot No. 1 Normal Seeding		Lot No. 2 18" Rows		Lot No. 3 Plants 18" x 18"	
	(a) Mature	(b) Immature	(a) Mature	(b) Immature	(a) Mature	(b) Immature
9						8
11						30
13						38
15	1	1		5		21
17	16	44	3	37	8	3
19	75	54	86	49	80	
21	8	2	10	9	12	
23			1			
Range	16 - 22	15 - 21	17 - 23	15 - 22	17 - 22	4 - 14
Mean	18.8 ± 0.07	18.14 ± 0.075	19.18 ± 0.054	18.24 ± 0.097	19.08 ± 0.06	12.62 ± 0.128
Standard Deviation	1.04 ± 0.049	1.11 ± 0.052	0.8 ± 0.038	1.44 ± 0.068	0.89 ± 0.042	1.91 ± 0.09
Co-Efficient of Variation	5.50	6.10	4.20	7.90	4.70	15.10

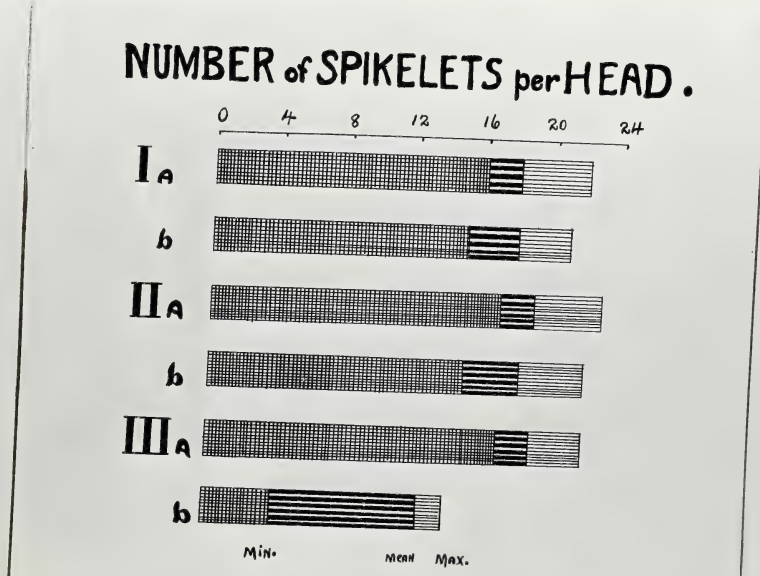


Fig. 5. Number of spikelets per head. The range, minimum, mean and maximum number of spikelets per head are represented.

The data collected in studying this character provided a surprise in that the number of spikelets in the mature heads appeared to be relatively constant irrespective of length of head and the spacing of the plant on which it was borne. The slight variation in the means of this class as shown in Table V and illustrated in Fig. 5 indicate that the number of spikelets per head is one of the most constant characters studied.

There appeared to be a relationship between the number of spikelets per head and the maturity: the later the maturity of the head the smaller appears to be the number of spikelets. It would seem as though each successive tiller produced was a little later in maturity and developed a correspondingly smaller number of spikelets than the preceding.

Table V and Fig. 5 shows that in all cases the number of spikelets on the immature heads is less than on the mature heads and that the range, standard deviation and co-efficient of variation is highest in the immature heads.

Density of Head

The length in m.m. of the ten lower internodes of the spike was taken as a value to represent the density of the head.

The density of the head is of particular significance in the differentiation of varieties and strains of wheat. The study of this character is of particular interest in this case as it proved to be extremely variable. The range as given in Table VI shows that some heads are almost twice as lax as others in the same group.

TABLE VI.

Density of Head in m.m.

Mid Class Values	Lot No. 1 Normal Seeding (a) Mature	Lot No. 2 18" Rows (a) Mature	Lot No. 3 Plants 18" x 18" (a) Mature	Lot No. 3 Plants 18" x 18" (b) Immature
32.5	5			
37.5	28	17		
42.5	29	19		
47.5	35	24		2
52.5	3	31		4
57.5		7	4	3
62.5		2	18	24
67.5			39	36
72.5			24	23
77.5			11	6
82.5			4	2
Range	32 - 50	35 - 60	57 - 83	46 - 85
Mean	42.65 ± 0.329	47.4 ± 0.432	69.1 ± 0.371	67.05 ± 0.438
Standard Deviation	4.88 ± 0.229	6.4 ± 0.3	5.65 ± 0.265	6.48 ± 0.304
Co-efficient of Variation	11.40	13.50	8.20	9.70

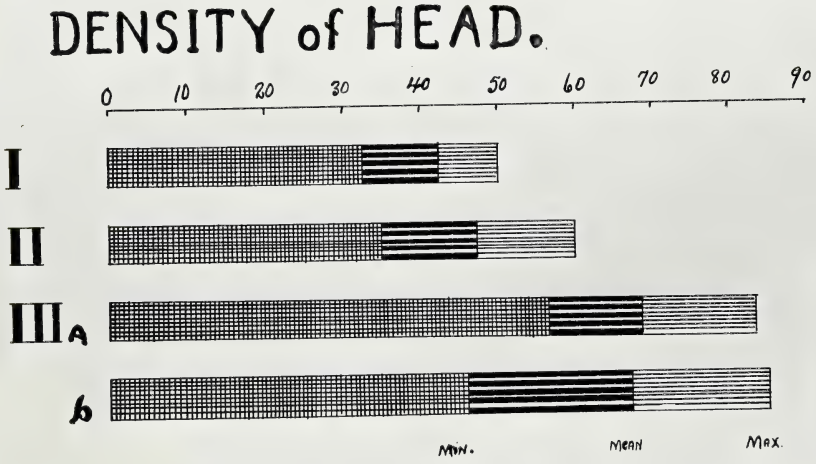


Fig. 6. Density of Head. The range, minimum, mean and maximum density of head are represented.

Table VI and the graph in Fig. 6 show the variation in the density. It will be seen that the mean length of the ten lowest internodes increases as the plants were allowed more room to develop. Since the length of head increases as the interspace between plants increases and since the number of spikelets is fairly constant on all fully developed heads, it would seem as though there was a correlation between density and length of head. The density varies inversely as the length of the ten lowest internodes and also inversely as the length of the head.

The relationship between density and length of head is not constant between individual plants nor between individual heads on the same plant; for example, one case was found where the immature heads on one plant varied in density from 4.7 to 8.2 while two heads of similar length produced by this same plant--see Fig. 10A--exhibited a wide range in density being 120 m.m. long and with a density of 64 m.m. in the one case against 135 m.m. long with a density of 80 m.m. in the second. It will be seen that these extreme combinations might cause considerable difficulty were varieties differentiated by this character alone.

In speaking of density of head Newman (9) describes Marquis as "mid-dense under normal conditions, but under other conditions may be fairly lax or quite dense." In speaking of density of head in general Newman states, "The density of the spike is affected very appreciably by the general development of the plant. Spikes which are abnormally developed , as often is the case along the margin of fields or plots, are

likely to be more open or "lax" than are those which have developed normally. Similarly, heads which are subnormal in development, as when borne on late developing tillers, are likely to be more dense. It is important, therefore, to note the general development of the plant before taking the density of spike into consideration and even then there is some danger of attaching too much importance to so variable a character, although the latter often may be of considerable assistance." His statements are in agreement with the findings of this investigation.

Glumes

The glume is a very important plant character in wheat variety and strain differentiation. There has been considerable discussion during the past five years concerning the variability of this character. To date, very little definite knowledge is available, although opinions are rampant.

The length of glume was studied in a statistical way. The glume selected on each head for measurement was the secondary glume of the fourth fertile spikelet from the base of the spike. The measurement for length of glume was taken from the base of the glume to the base of the beak or at the point of greatest angularity where the beak and shoulder join. The measurement was made by placing one point of a caliper at the base of the glume and the other point at the base of the beak, this measurement was transferred to a metric scale and recorded.

The related data in Table VII and Fig. 7 , when analysed shows that the mean length of the glume increases from Lot 1 to Lot 3 and that the mean length of the glumes of the immature

heads of Lot 3 is greater than the length of the glumes of the mature heads of the same group. While there is a slight difference in the mean length of the glumes of the different Lots, the co-efficient of variation indicates that glume length is the least variable of the characters studied.

TABLE VII

Length of Glume in m.m.

Mid Class Values	Lot No. 1 Normal Seeding (a) Mature	Lot No. 2 18" Rows (a) Mature	Lot No. 3 Plots 18" x 18" (a) Mature	Lot No. 3 Plots 18" x 18" (b) Immature
7.0	1			
7.5		1		
8.0	30	17	2	2
8.5	21	14	12	1
9.0	48	63	69	49
9.5		2	10	23
10.0		3	7	25
Range	7.0 - 9.0	7.5 - 10.0	8.0 - 10.0	8.0 - 10.0
Mean	8.57 ± 0.032	8.78 ± 0.03	9.04 ± 0.026	9.34 ± 0.031
Standard Deviation	0.469 ± 0.020	0.438 ± 0.021	0.379 ± 0.018	0.465 ± 0.022
Co-efficient of Variation	5.50	5.00	4.20	4.00

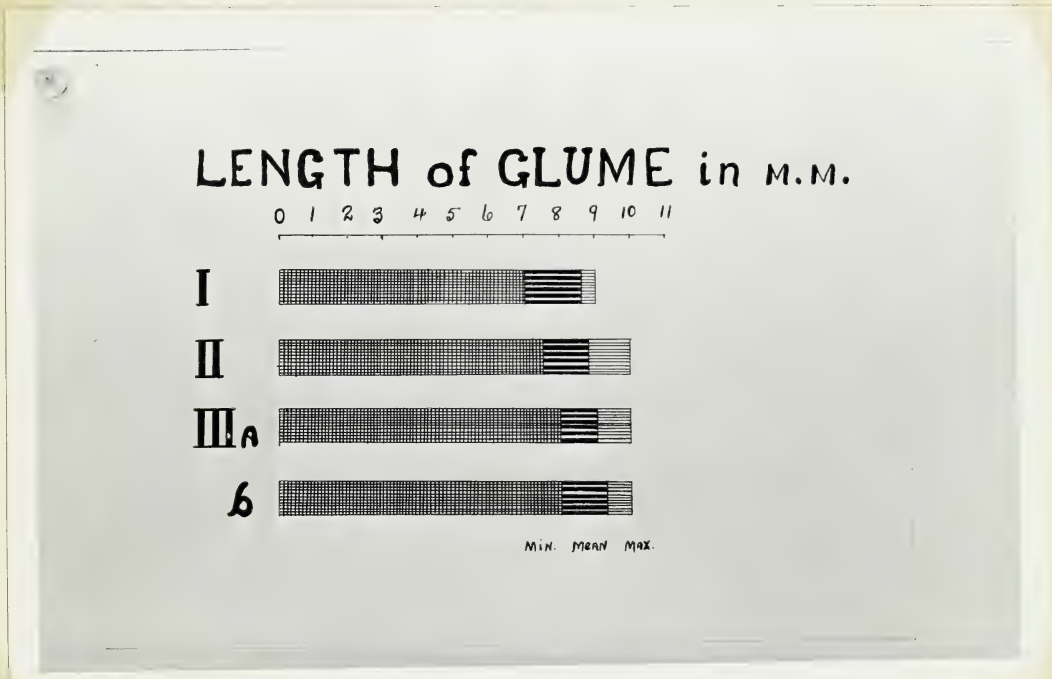


Fig. 7 Length of Glume. The range, minimum, mean and maximum length of glume are represented.

A study was made of the effect of maturity on the shape of the glume. It was observed that the glume of Marquis wheat progresses through certain stages of development coincident with the progression of the maturity of the plant from the flowering stage to the fully developed kernel. These successive stages of development are illustrated in Fig.8 . A. represents the contour of a typical glume during the flowering stage of the plant. The glume at this stage is upright in growth and has a slightly elevated shoulder. B. represents the shape of the glume after the kernel has started to develop. The glume has broadened out and the shoulder is more nearly at right angles to the beak. C. represents the glume when the kernel is fully grown in size but is still in the watery stage. The increase in the size of the kernel has bent the glume backward and a buckle develops near the base of the keel. The bending backward apparently changes the whole contour of the glume. It will be seen that as the glume is forced backward the outer point of the shoulder is pulled downward by a shearing movement, thus changing the angle of the shoulder from a slightly elevated to a slightly oblique position. D. represents a fully matured glume from a spikelet that bore four or more fully matured kernels. It will be seen that a decided buckle has developed near the base of the keel, that the obliqueness of the shoulder is quite pronounced, and that the glume appears both shorter and broader. Mature glumes from spikelets which have borne two to three kernels would be similar to B. and C. except

that they tend to broaden out in the centre. This observation is in agreement with Newman's (9) description of Marquis wheat. In describing glume shape he states, "Shoulder of empty glume of secondary floret on seventh node from base of spike, square to slightly elevated under normal conditions. Under conditions which force an abnormal growth and more open head the shoulder of the glume is likely to be quite oblique, while under sub-normal conditions the shoulder may be decidedly elevated."

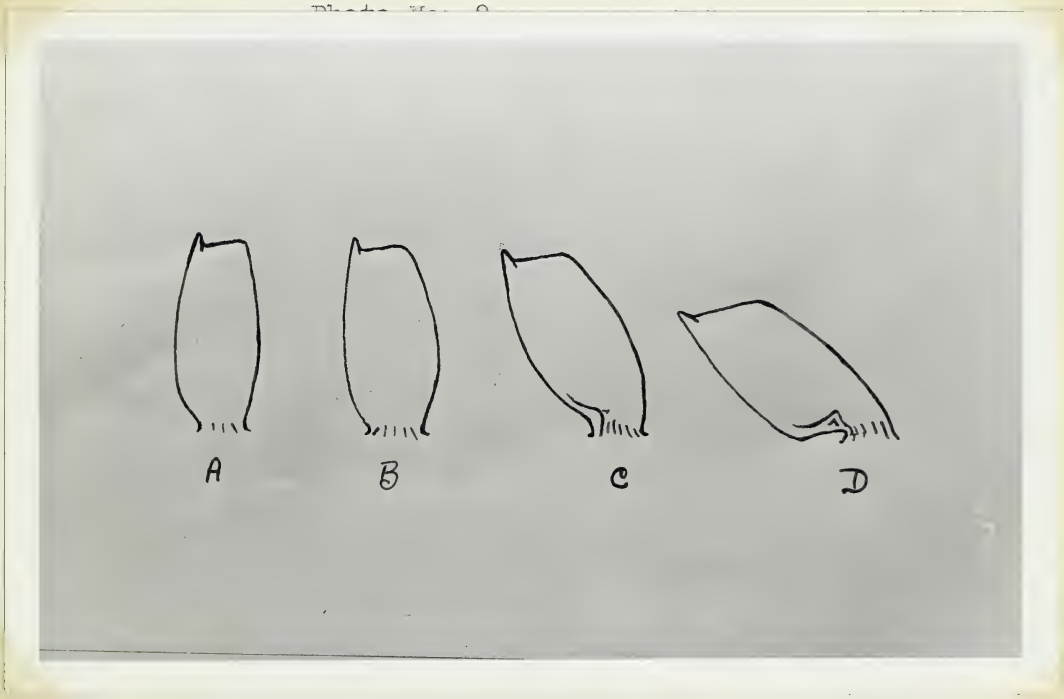


Fig. 8. Glumes of Marquis 10B wheat illustrating the changes noted in the shape of the glume as the plant progresses from the flowering stage (A) to full maturity (D).

Fig. 9. Heads of Marquis 10B wheat showing the variations in the number of fertile and infertile spikelets, length and shape of head.

Fig. 10. A. Two heads of Marquis 10B wheat taken from the same plant showing extreme variation in density. B. Plant of Marquis 10B wheat showing extreme variation in length of tiller. The group of tillers on the left are fully matured and are shorter and less variable in length than the group of immature tillers on the right.

CONCLUSIONS

1. The tiller of the Marquis wheat plant may be very variable in length and maturity. While the earliest maturing tillers are usually taller certain later maturing tillers, when environmental conditions are favorable, may grow so much taller than other tillers on the same or adjoining plants that they at once raise a doubt in the mind of the observer as to their parentage.

2. The head of the Marquis wheat plant, when grown under varying environmental conditions, shows a wide range in length, shape, density and general appearance. They may vary so much that it would be difficult for anyone not intimately acquainted with Marquis type to identify heads grown under different environmental conditions, as being genuine Marquis.

3. Glume length appeared to be the most constant of the characters of Marquis wheat studied.

4. The glume progresses through certain stages of development coincident with the progression of the maturity of the plant from the flowering stage to the fully developed kernel.

5. In view of the extreme variation in Marquis wheat which appears to be directly attributable to differences of environment and maturity, it is essential that heads

of similar maturity and grown under similar environmental conditions should be selected for strain comparisons.

6. The data presented in this paper indicate that Marquis 10 B wheat in particular is subject to a wide range of "fluctuation" or "variation from the mean" variety type, and suggests the likelihood that other strains of Marquis and other varieties of wheat are also subject to extreme variations in morphological characters when grown under varying conditions of environment.

7. While the foregoing conclusions are the result of several years of general observations and of the interpretation of considerable data, the statistical study is the result of one year's work only. The problem is undoubtedly important enough to warrant further study either to substantiate or to modify the conclusions drawn.

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